ELECTRIC VEHICLE TEST PROCEDURE

SOUTHERN CALIFORNIA
EDISON

An *EDISON INTERNATIONAL* Company

ELECTRIC TRANSPORTATION DIVISION

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I. INTRODUCTION

Since this test procedure was originally written in 1995, the type of electric vehicle (EV) tested at the Electric Vehicle Technical Center (EV Tech Center) in Pomona, California has changed dramatically. Instead of prototypes and small-scale production models, most vehicles tested are now production vehicles from major manufacturers, and most are very refined, with acceleration and braking characteristics close to that of gasoline-powered vehicles.

At first, weight certification was mainly a safety issue, as converted vehicles sometimes exceeded their original gross vehicle weight rating (GVWR). With current production vehicles the total vehicle weight is usually well within the specified gross vehicle weight rating, and the issue is a more practical one – related to passenger and cargo capacity.

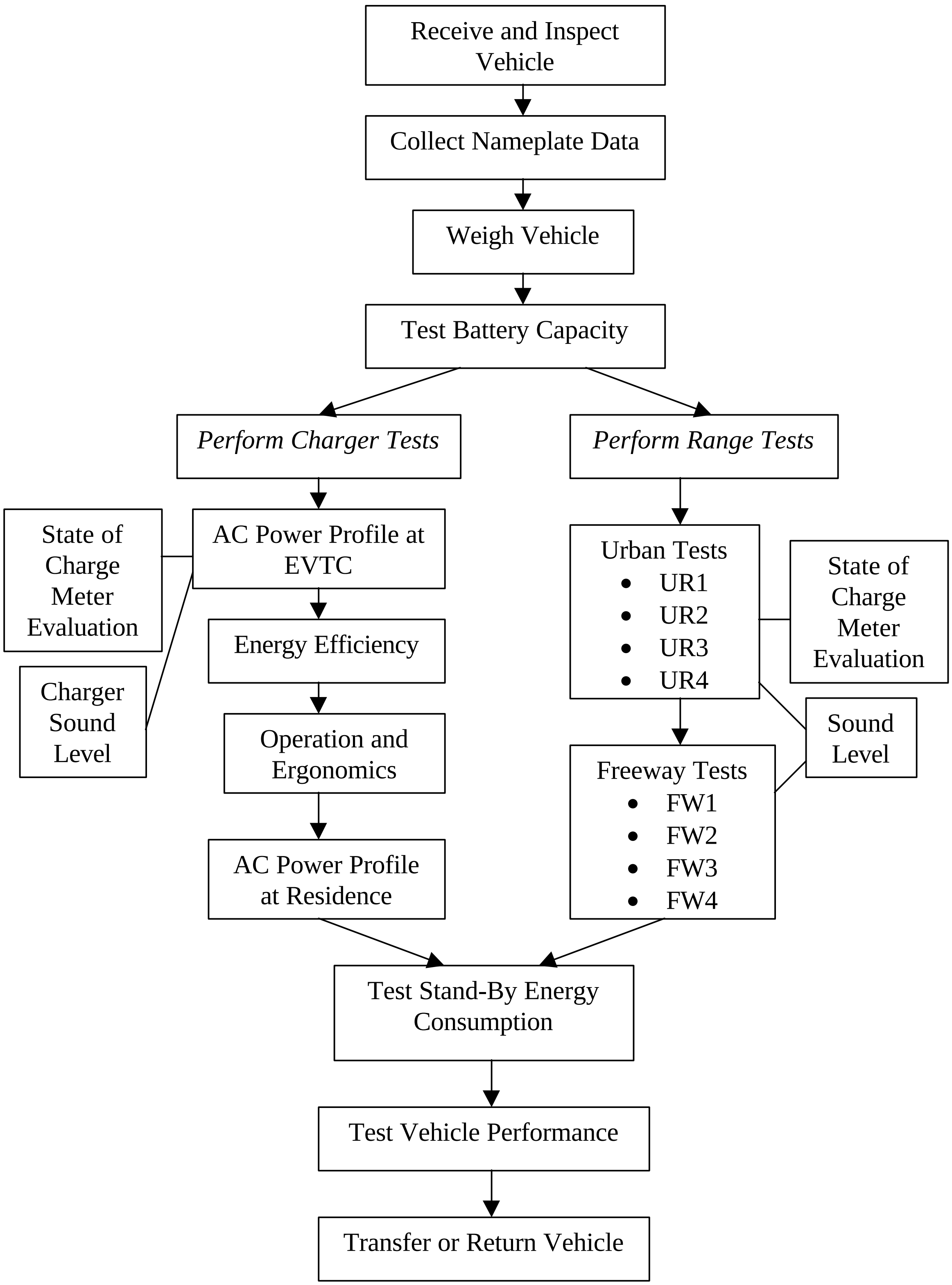
Range tests under different vehicle conditions no longer always have predictable results. Automatic climate controls limit air conditioner power on cool days, thus conserving battery energy and increasing range. The battery pack and the output side of the charger may no longer be readily accessible; some manufacturers may not allow access. Therefore, not all of the following charger and battery test procedures or efficiency measurements can be performed on all vehicles.

Since chargers are associated with each electric vehicle, the EV evaluation must include testing of the charger. As the use of EVs and their associated chargers increase, the potential for local demand and power quality problems increases. The combined impact of many chargers on the whole of the electric utility system could be detrimental. In order to plan properly, and to encourage manufacturers to build satisfactory chargers, the individual contribution of each type of charger must be determined through testing.

This publication describes testing methods and evaluation criteria used by the Electric Transportation Division of Southern California Edison to evaluate electric vehicles and chargers. These procedures are followed for each EV test unless otherwise noted in the test report. The document is divided into four main parts: Test Plan, Test Instrumentation, Test Procedure, and Appendices. The Test Plan gives an outline of tests performed and the reasons or justification for the procedures. The Test Instrumentation section is a listing of the required equipment for each procedure. The Test Procedure section gives detailed instructions on how to perform the tests. The Appendices include maps, data sheets, and diagrams.

The EV Tech Center maintains a network database (called “Project Manager”) for test reports, results, and standard forms. The intent is to allow EV Tech Center personnel access to all current and past projects and test data in the interest of sharing information. As data is gathered during a test, it is entered in the database on the standard forms mentioned in the test procedure.

SCE EV TEST PROCEDURE FLOW DIAGRAM



II. TEST PLAN

A. NAMEPLATE DATA COLLECTION

Record all applicable nameplate data, serial numbers, and ratings for all tested components. This data is important to record in order to keep track of the version of the software and hardware of the vehicle, since this technology can change rapidly.

B. WEIGHT DOCUMENTATION

At a certified scale, measure the weight of the vehicle. The curb weight is subtracted from the GVWR to determine the available payload.

C. BATTERY CAPACITY TEST

The battery capacity test should be performed before the range tests to determine the pack's health. Follow the USABC (United States Advanced Battery Consortium) procedure for constant current discharge tests. Use the ABC-150 battery tester to discharge the EV's battery pack at a constant current until a manufacturer recommended cutoff voltage is reached. At a starting battery temperature of $23^{o} \pm 2^{o}$ C, perform groups of three constant current discharge cycles at each of $C_3/3$, $C_2/2$, $C_1/1$, and $C_3/3$ Amperes. Repeat until the $C_3/3$ capacity is stable with three consecutive discharges within 2%. Construct a Peukert Curve, which shows the effect of discharge rate on capacity and can be used to determine the battery capacity at a specific rate.

D. RANGE TESTS

Repeat the tests until the range result is within 5.0% of the previous result. Report the average of the final two tests.

1. **UR1** - Urban Range Test at Minimum Payload (driver and test equipment only).
   Drive the EV on the "Urban Pomona Loop" without using auxiliary loads. Record data to determine distance per charge, AC kWh/mile, and DC kWh/mile.
   The "Urban Pomona Loop" is a local street route of about 20 miles with approximately 50 stop signs and traffic lights. Refer to the Appendix, p.20, for a map and elevation profile.

2. **UR2** - Urban Range Test at Minimum Payload with Auxiliary Loads.
   Repeat the above test with the vehicle's auxiliary loads on (air conditioning, lights, and radio). Record air conditioning vent temperature and cabin temperature continuously.

3. **UR3** - Urban Range Test at Maximum Payload (GVWR)
   Urban Pomona Loop range test with auxiliary loads off and with the vehicle loaded to its maximum legal weight limit.

4. **UR4** - Urban Range Test at Maximum Payload (GVWR) With Auxiliary Loads Repeat the above test with auxiliary loads on. Record air conditioning vent temperature and cabin temperature continuously.

5. **FW1** - Freeway Range Tests at Minimum Payload
Drive the EV on the "Freeway Pomona Loop" without using auxiliary loads. Record data to determine distance per charge, AC kWh/mile, and DC kWh/mile.
The Freeway Pomona Loop is a loop on four local freeways of approximately 37 miles (one transition requires one-half mile on access roads). Refer to the Appendix, p.16, for a map and elevation profile.

6. **FW2** - Freeway Range Test at Minimum Payload with Auxiliary Loads
Repeat the above test with the vehicle's auxiliary loads on. Record air conditioning vent temperature and cabin temperature continuously.

7. **FW3** - Freeway Range Test at Maximum Payload (GVWR)
Pomona Freeway Loop range test with auxiliary loads off and with the vehicle loaded to its maximum legal weight limit.

8. **FW4** - Freeway Range Test at Maximum Payload (GVWR) With Auxiliary Loads
Repeat the above test with the vehicle's auxiliary loads on. Record air conditioning vent temperature and cabin temperature continuously.

E. SOUND LEVEL TEST

The interior cabin sound level will be measured for one urban and one freeway loop. A recorded plot from the meter and an average sound level will be reported.

F. STATE OF CHARGE METER EVALUATION

1. Driving
While performing the Urban Range Tests, record data to produce a distance traveled vs. state-of-charge graph.

2. Charging
While charging, record data to produce a state of charge vs. time graph. Plot with the charging profile to associate indicated state of charge with energy delivered.

G. PERFORMANCE TESTS

The acceleration tests are designed to measure peak power capability of the vehicle and battery pack on the test track. Use the accelerometer performance computer to measure the time, speed, and acceleration. The tests will be performed in the sequence and number described in the test procedure in order to minimize heating effects on the traction battery. The vehicle will be driven gently between tests to discharge.

1. **Acceleration**
   Accelerate the EV from a stop to over 60 mph at maximum power. Repeat this procedure two times in opposite directions (to average the effects of wind and grade) at the following traction battery states-of-charge: 100%, 80%, 60%, 40%, and 20%, as measured by the EV's state of charge gage. Read the data from the computer to obtain the time for 0-30 mph and 0-60 mph.

2. **Maximum Speed**
   Continue to accelerate the EV from the 60 mph test until the maximum speed is reached. Conduct twice in opposite directions at both 100% and 20% SOC.

3. **Acceleration - 30 to 55 mph**
   Accelerate the EV from a steady 30 mph to 55 mph at maximum power. Perform this procedure twice in opposite directions at the following approximate traction battery states-of-charge: 100%, 80%, 60%, 40%, and 20% (after the above tests).

4. **Braking**
   Brake the vehicle from a steady 25 mph without skidding the tires. Repeat this procedure four times in opposite directions. Use the performance computer to determine braking distance. This test will be performed between 50% and 60% SOC.

H. CHARGER PERFORMANCE/CHARGING PROFILE TEST

1. **AC Input Data**
   Use the BMI Power Profiler to record the following on the AC (input) side of the charger for the duration of the charge at the EV Tech Center:
   - Real, reactive, and apparent power
   - Energy consumption
   - True and displacement power factors
   - Voltage and current total harmonic distortion
   - Current total demand distortion
   - Voltage, current, and frequency
   - Ambient temperature and humidity

2. **Charging Profile**
   Use the ABB Recording kWh Meter recording at one-minute intervals to collect AC demand and energy data.

3. **Charging at a Residential Setting**
   While standard power quality measurements are made at SCE’s EV Tech Center, it is useful to know what the effects of the charger are in a “real world” setting, as the type of service can affect results. In order to observe the power quality of the charger through a typical residential service; charge the vehicle at a designated residence. Use the BMI Power Profiler to record energy and power quality

characteristics. Use the portable ABB Recording kWh Meter to collect AC demand and energy data.

4. Charger Energy Efficiency

If the output side of the charger is accessible, use the SmartGuard Control Center to record Voltage, current, power, and energy data. Use the results to determine the charger energy efficiency.

5. Audible Noise Levels

Use a sound level meter to measure charger noise intensity at maximum power from a distance of one meter.

6. Operation and Ergonomics

Observe these aspects of the charger's operation:

- Charging algorithm
- Battery monitoring
- End point determination
- Protective features

Examine the user's interface with the charger:

- Switches, indicators, displays
- Dimensions, weight
- Connector types
- Ease of use

I. STAND-BY ENERGY CONSUMPTION TESTS ("HOTEL" LOADS)

1. Vehicle on Charger

After recharging the battery pack to 100% SOC, record the amount of AC kWh drawn by the charger and the DC kWh being delivered to the batteries for a 24 hour period.

2. Vehicle off Charger

After completing the preceding test, disconnect AC Power supply from the charger and record the amount of DC kWh consumed by the vehicle for a 24-hour period.

J. TRANSFER THE VEHICLE

Once the vehicle has undergone a full performance test, it must be transferred to the Transportation Services Department in order to place it in its intended service. If the vehicle is on loan it must be returned to the owning organization.

III. TEST INSTRUMENTATION

A. WEIGHT DOCUMENTATION

1. Certified Weight Scale

B. RANGE TESTS

1. EV odometer
2. Thermometer
3. Temperature loggers (2)
4. SmartGuard Control Center
4. Laptop computer
5. BMI Power Profiler

C. BATTERY CAPACITY TEST

1. Aerovironment ABC-150 Battery Cycler
2. SmartGuard Control Center
3. Digital multimeter
4. Thermometer

D. SOUND LEVEL TEST

1. Sound level meter
2. Laptop computer (optional)

E. STATE OF CHARGE METER EVALUATION

1. EV odometer
2. EV state-of-charge meter
3. Stopwatch

F. PERFORMANCE TESTS

1. Acceleration Tests
    a. EV speedometer
    b. Stopwatch
    c. EV state-of-charge meter
    d. Vericom VC2000PC Performance Computer

2. Maximum Speed
    a. EV speedometer

3. Braking
    a. EV speedometer
    b. Vericom VC2000PC Performance Computer

G. CHARGER PERFORMANCE/CHARGING PROFILE TEST

1. BMI Power Profiler 3030A
2. ABB Recording kWh Meter
3. Laptop computer
4. SmartGuard Control Center
5. EV state-of-charge meter
6. Stopwatch
7. Decibel Meter

H. STAND-BY ENERGY CONSUMPTION TESTS (HOTEL LOADS)

1. Vehicle on charger:
    a. BMI Power Profiler
    b. SmartGuard Control Center
2. Vehicle off charger:
    SmartGuard Control Center

IV. TEST PROCEDURE

A. NAMEPLATE DATA COLLECTION

Record all applicable nameplate data, serial numbers, and ratings for all tested components and test equipment on the Equipment and Nameplate Data Sheet (EVTC–040) (see page 33). On the vehicle, readily available data should be recorded for the controller, motor, charger, traction battery, tires, payload, etc.

B. WEIGHT DOCUMENTATION

Take the EV to a certified scale and measure the curb weight of the vehicle, as well as the weight on each axle. Enter the data on the Weight Certification form available on "Project Manager".

C. BATTERY CAPACITY TEST

Before attempting the battery capacity test, obtain documents containing specifications and recommended values and procedures from the battery manufacturer. The specifications should include a range for which the specified capacity is acceptable so that the health of the battery can be determined.

Data Acquisition Equipment
If possible, and permissible with the manufacturer, configure the vehicle with the SmartGuard Control Center (SGCS) system to record current and voltage information from the battery pack. Using piercing voltage probes and a current transformer probe on the high voltage cables on the output side of the battery pack, connect to the SGCS. If access to the battery pack is possible, configure each module with a Smart Guard unit. Connect the SGCS to the ABC-150.

Fully charge the battery pack with the vehicle's charging system (or use the battery manufacturer's charge algorithm). Take the pack off charge at least 30 minutes before beginning the discharge test. Connect the ABC-150 battery tester to the main battery pack. Record on the Vehicle Battery Capacity Test form (EVTC-060) (see page 35) the initial open circuit pack voltage, pack average temperature and ambient temperature with the SGCS. The pack average temperature can be obtained with the vehicle's diagnostic tool or with thermocouples placed on modules at various pack locations.

Use the ABC-150 battery tester to discharge the EV's battery pack at a constant current until a manufacturer recommended cutoff voltage is reached. Record the following data at 10 second intervals: pack current, pack voltage, Ah, kWh, module Voltage, module temperature.

At a starting battery temperature of $23^o \pm 2^o$ C, perform groups of three constant current discharge cycles at each of $C_3/3$, $C_2/2$, $C_1/1$, and $C_3/3$ Amperes. At the end of each test, record the following data: open circuit pack voltage (at least 30 minutes after the end of discharge), ambient temperature, average pack temperature, the Voltage difference at the stop condition, the lowest module at the stop condition, DC Ah out, and DC kWh out. Repeat until the $C_3/3$ capacity is stable with three consecutive discharges within 2%.

Charge the vehicle with the vehicle's charger, and record the AC kWh input to the charger and the DC kWh used to return the pack to a fully charged state. Divide the DC kWh returned by the DC kWh out to determine the percent overcharge.

Construct a Peukert Curve – a plot of the logarithm of the discharge rate versus the logarithm of the discharge time to a specified end-of-discharge voltage (Figure 3-1). The curve shows the effect of discharge rate on capacity and can be used to determine the battery capacity at a specific rate.

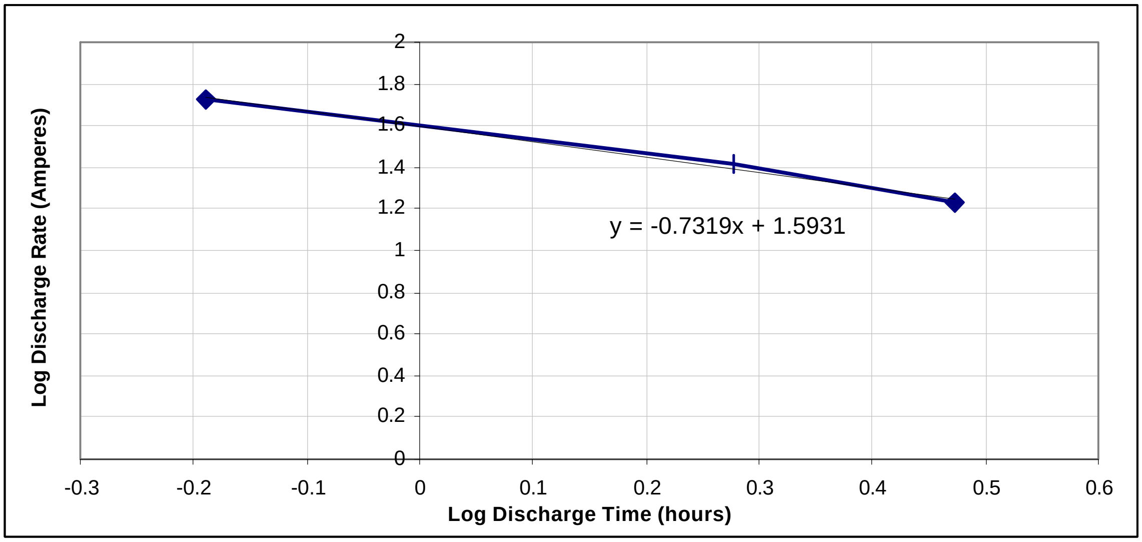


Figure 3-1. Sample Peukert Curve.

D. RANGE TESTS

Vehicle Preparation/Inspection

All new vehicles should first be inspected using the New Vehicle Turnkey Inspection form available from Transportation Services Department (TSD), Pomona. The New Vehicle Turnkey inspection is typically conducted by TSD. All other tested vehicles should be subjected to the functional testing on that form. Inflate tires to the maximum pressure indicated on the tire sidewall. Check the pressure at least once per week. Check the vehicle fluid levels once per week.

Data Acquisition Equipment

If possible, and permissible with the manufacturer, configure the vehicle with the SmartGuard Control Center (SGCS) system to record current and voltage information from the battery pack. Using piercing voltage probes and a current transformer probe on the high voltage cables on the output side of the battery pack, connect to the SGCS. Connect the SGCS to a laptop computer to record data at 30 second intervals during driving.

Stop Conditions

The maximum useable range of the EV is determined by vehicle gage indications specified by the manufacturer, or if no instructions are specified, by diminished vehicle performance such that the EV is no longer capable of operating with the flow of traffic. Typically, a vehicle will have two warning lights near the end of the vehicle's range. The first is usually a cautionary light at roughly 20% SOC. This light is usually a reminder to the driver that he should notice that the state of charge is low. The second warning usually comes on at about 10% to 15% SOC, and is an indication to charge immediately. The EV Tech Center usually uses this second warning signal, as recommended by the manufacturer, to stop the range test, so that there is no chance to harm the traction battery by overdischarge. At this point, the driver should be within a mile or two of the EV Tech Center, and he will drive it in slowly and conservatively. If the vehicle is five miles or more from the EV Tech Center, the driver will have it towed in.

1. Urban Range Tests:

Record the pack voltage, odometer reading and ambient temperature on the Pomona Driving Test Data sheet (EVTC-010) (see page 30). Drive the EV on the Urban Pomona Loop in a manner that is compatible with the safe flow of traffic. Record the following data on the EVTC-010 form at five-mile intervals (or at intervals determined by the vehicle's state of charge meter, if it has sufficient graduations to correspond to about five miles driving between marks): state of charge meter reading, pack voltage, DC kWh, and odometer mileage.

Near the end of the drive, if needed to manage the range, it is permissible to reverse direction after completing a partial loop, or to shorten the loop by using a parallel street; record this deviation (and all other deviations from the Pomona Loop) on the EVTC-010. Record the distance traveled (to the tenth of a mile) at the stop condition and at the end of the drive.

Upon returning to the EV Tech Center, record the end of test data (odometer, state of charge, ambient temperature, DC kWh, and pack voltage after 30 minutes).
Connect the BMI Power Profiler to the AC supply side, and collect data necessary for the *Charger Performance Test* (see p. 16) after the first and second UR-1 tests. For the remaining tests, after completion of charging, record the AC kWh data from the BMI Power Profiler, and the DC data, if applicable, from the SmartGuard system.

Conduct this procedure in the following four vehicle test configurations:

UR-1 Minimum payload (driver only) with no auxiliary loads.

UR-2 Minimum payload (driver only) with the following auxiliary loads on: air conditioning set on high, fan high, low beam headlights, and radio. Use thermocouple temperature loggers to continuously record the temperature of the air-conditioned outlet air from the center cabin vent and the cabin ambient temperature at mid-cabin chest level.

UR-3 Repeat the UR-1 test at the vehicle's maximum legal weight limit (without exceeding the gross axle weight ratings).

UR-4 Repeat the UR-2 test at the vehicle's maximum legal weight limit (without exceeding the gross axle weight ratings).

Repeat the tests until the range result is within 5.0% of the previous result. Report the average of the final two tests.

2. Freeway Range Tests:

Record the pack voltage, odometer reading, and ambient temperature. Drive the EV (with windows closed) on the Freeway Pomona Loop in a manner that is compatible with the safe flow of traffic. Maintain speed on the freeway as close to 65 mph as possible; drive conservatively on the transitions. Record the following data on the EVTC-010 form at five-mile intervals (or at intervals determined by the vehicle's state of charge meter, if it has sufficient graduations to correspond to about five miles driving between marks): state of charge meter reading, pack voltage, DC kWh, and odometer mileage. Note the current being delivered by the battery pack at a constant 65 mph on the 10 Freeway between Haven Street and Milliken Avenue.

Near the end of the drive, if needed to manage the range, it is permissible to reverse direction after completing a partial loop; record this deviation (and all other deviations from the Freeway Loop) on the EVTC-010. Leave the freeway loop only at Towne Avenue or Indian Hill Boulevard, if on the 10 Freeway, or Reservoir Street if on the 60 Freeway to minimize city driving. Record the distance traveled (to the tenth of a mile) at the stop condition and at the end of the drive.

Upon returning to the EV Tech Center, record the end of test data (odometer, state of charge, ambient temperature, DC kWh, and pack voltage after 30 minutes).
Connect the BMI Power Profiler to the AC supply side to record energy data. After completion of charging, read the AC kWh data from the BMI Power Profiler, and the DC data from the SmartGuard Control Center system.

Conduct this procedure in the following four vehicle test configurations:

FW-1 Minimum payload (driver only) with no auxiliary loads.

FW-2 Minimum payload (driver only) with the following auxiliary loads on: air conditioning set on high, fan high, low beam headlights, and radio. Use thermocouple temperature loggers to continuously record the temperature of the air-conditioned outlet air from the center cabin vent and the cabin ambient temperature at mid-cabin chest level.

FW-3 Repeat the FW-1 test at the vehicle's maximum legal weight limit (without exceeding the gross axle weight ratings).

FW-4 Repeat the FW-2 test at the vehicle's maximum legal weight limit (without exceeding the gross axle weight ratings).

Repeat the tests until the range result is within 5.0% of the previous result. Report the average of the final two tests.

AC kWh per mile efficiency

To determine the AC kWh per mile efficiency, recharge the pack fully and use the BMI Power Profiler to record the energy consumption in AC kWh; this number divided by the number of total miles driven, will yield an approximate figure for AC kWh per mile efficiency.

Range Envelope

Once all the data for the range tests have been gathered, a "Range Envelope" can be created for the vehicle for both urban and freeway driving (Figure 3-2). To construct the envelope, use the range in miles recorded at the stop condition; this is a more consistent value than the total miles driven (which may vary based on the distance the driver is from the EV Tech Center when the stop condition is reached) and can be more easily used by others to estimate range. Typically, the longest range will be achieved when the vehicle is tested at minimum payload with no auxiliary loads, and conversely, the shortest range will be achieved with a fully loaded vehicle with all auxiliary loads turned on. Plotting these data should yield a chart similar to the one shown in Figure 3-2.

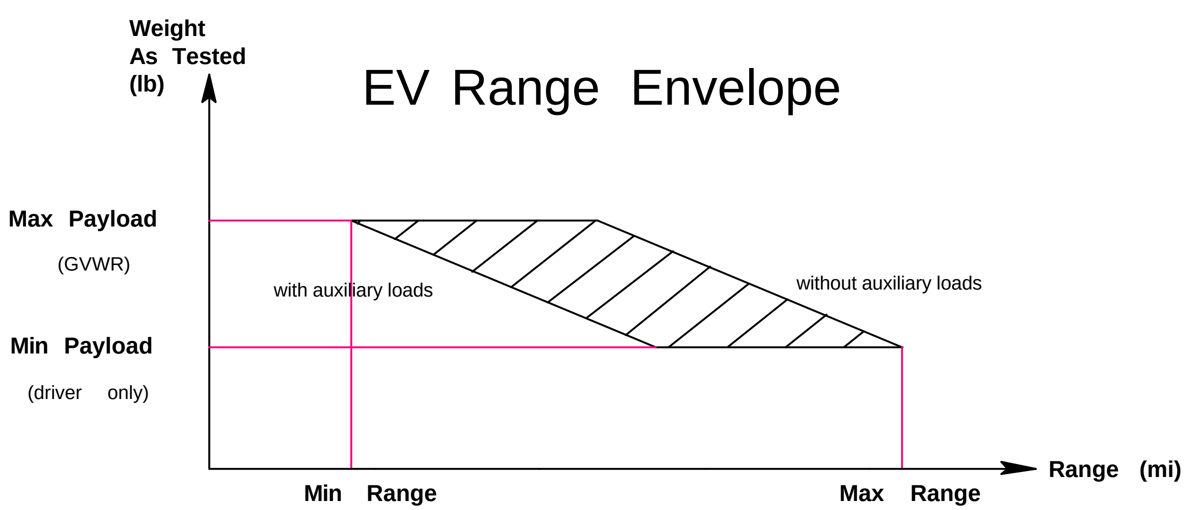


Figure 3-2. Range Envelope.

Air Conditioning Performance
Plot the two curves: air conditioning vent temperature versus time and cabin temperature versus time on the same graph.

E. SOUND LEVEL TEST

Position the sound level meter in the vehicle cabin at ear level on the passenger seat. Record the sound level for both one urban and one freeway loop. The windows will be rolled up and all interior accessories will be off. Any external noises from sources other than the test vehicle loud enough to register on the meter will be noted and reported on the Sound Level Test Data Sheet (EVTC-050) (see page 34). Report the average sound level and present the plot of the recorded data in the Performance Characterization report.

F. STATE OF CHARGE METER EVALUATION

1. Driving

While running the Urban Range Tests, record on the EVTC-010 the distance traveled using the EV's odometer at intervals corresponding to the EV's state-of-charge meter (such as 3/4, 1/2, 1/4 and "empty"). If the vehicle has only an energy meter, record data at five-mile intervals. At the end of the trip, record the total number of miles driven. In an ideal case, the maximum range would be reached at the time that the state of charge meter indicates "empty". An ideal state-of-charge meter would yield the following chart for an 80-mile maximum range vehicle:

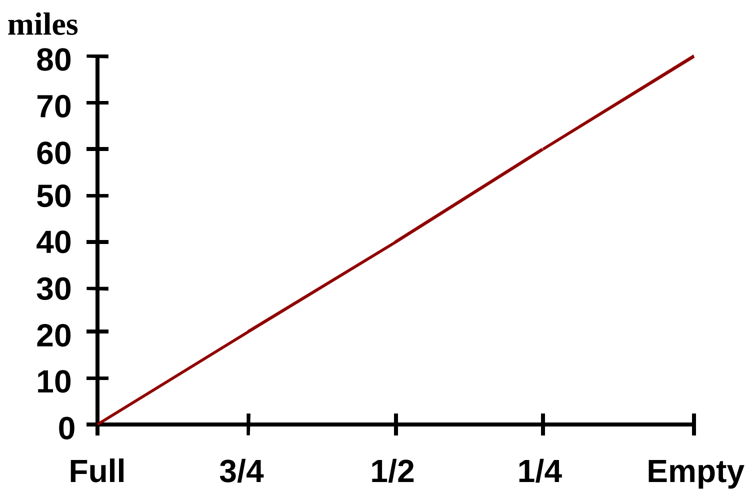


Figure 3-3. State of Charge Meter Evaluation.

2. Charging

During charging record on the EVTC-010 the state of charge reading on the EV's state-of-charge meter at fifteen-minute intervals. Use this data to create an indicated state of charge versus time graph, and plot with the charging profile and calculated state of charge plot. This plot will assist the user in estimating the state of charge after a certain amount of time and the energy needed to reach that state.

3. **Driving Range per Charging Time**

Use the results from (1) and (2) to estimate the vehicle range per charging time under UR1 conditions. Use the UR1 average range and state of charge data, to create a set of data points that show miles driven versus indicated state of charge. Subtract the range at each point from the maximum range at the stop condition to obtain a set of points giving the range available at each state of charge point. Use the results giving state of charge versus charging time from (2) to create a plot giving driving range available per charging time (Figure 3-4).

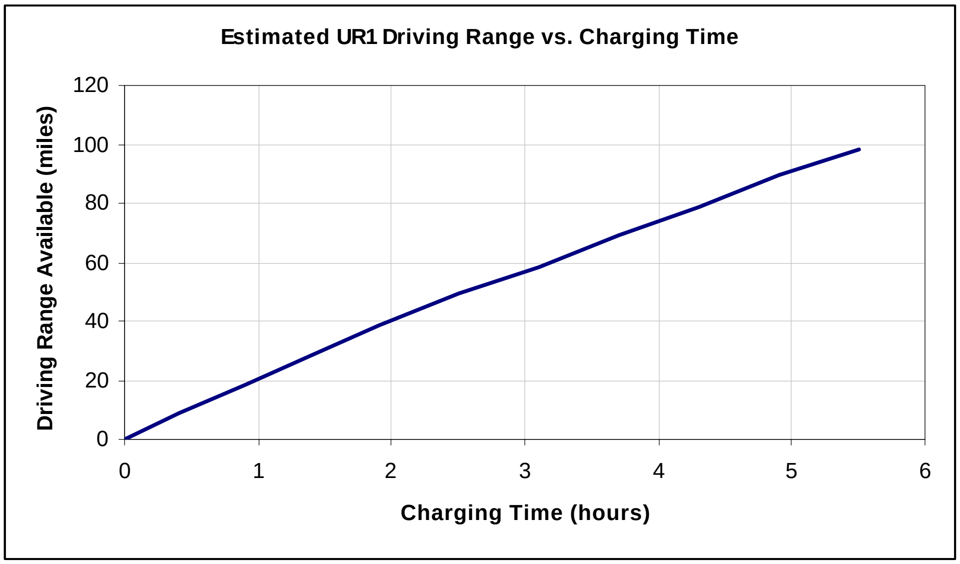


Figure 3-4. Sample plot of estimated range versus charging time.

G. PERFORMANCE TESTS

These tests will be performed with minimum payload at the Los Angeles County Fairplex drag strip in Pomona. Tires should be at maximum pressure. Record the starting and ending data on the EVTC-030 form (see page 32): odometer, ambient temperature, relative humidity, date, time, pack voltage. Note the maximum current and maximum power observed during acceleration.

1. Acceleration

Use the Vericom VC2000PC Performance Computer to measure the performance of the vehicle. Accelerate the EV from stop to over 60 mph at maximum power, and then stop. Record the time expired for 0 to 30 mph and from 0 to 60 mph on the EVTC-030 form. Repeat this procedure twice in opposite directions (to average the effects of wind and grade) at the following traction battery states-of-charge: 100%, 80%, 60%, 40%, and 20%, as measured by the EV's state of charge gage. Report the average of the readings at each state of charge level.

2. Maximum Speed

Continue to accelerate the EV from the 60 mph test until the maximum speed is reached. Conduct this procedure twice in opposite directions at both 100% and 20% SOC. Report the average of these readings. If unable to reach the maximum speed before the end of the track, note the highest speed achieved.

3. Acceleration - 30 to 55 mph

Accelerate the EV from a steady 30 mph to 55 mph at maximum power and use a stopwatch record the time expired. Repeat this procedure twice in opposite directions at the following approximate traction battery states-of-charge: 100%, 80%, 60%, 40%, and 20% (after the above tests), as measured by the EV's state-of-charge gage. Report the average of each pair of readings.

4. Braking

Drive the EV to a speed of 25 mph, and apply the brakes hard enough to bring the vehicle to a quick stop without skidding the tires. Use the Vericom VC2000PC Performance Computer to measure the braking distance. Make four runs in opposite directions, and report the average of these readings.

H. CHARGER PERFORMANCE/CHARGING PROFILE TEST

Enter results on form EVTC-020 (see page 31).

1. AC Input Data

After the first UR-1 range test, use the BMI Power Profiler to record the following on the AC (input) side of the charger for the duration of the charge at the EV Tech Center:

- Real, reactive, and apparent power
- Energy consumption
- True and displacement power factors
- Voltage and current total harmonic distortion
- Voltage, current, and frequency
- Ambient temperature and humidity

Monitor the vehicle's state of charge meter as specified for the State of Charge Meter Evaluation.

After completion of the charge note the maximum current reported by the BMI.

After the second UR-1 test, set up the BMI Power Profiler to record current total demand distortion instead of harmonic distortion. Charge the vehicle and record a snapshot at maximum, intermediate and minimum power. Record data for the duration of the charge at the EV Tech Center.

2. Charging Profile

After the first UR-1 test use the ABB Recording kWh Meter recording at one-minute intervals to collect AC demand and energy data. Read the meter and determine the total charging time.

3. Charger Energy Efficiency

Use the SmartGuard Control Center as described in Range Tests to record voltage and current data on the output side of the charger. Use the results to determine the charger energy efficiency.

4. Data Analysis/Reports

Using the ABB Meter data and a spreadsheet program, plot the power versus time curve. Plot the instantaneous indicated state of charge on the same graph. Use the charger efficiency and energy data to plot calculated state of charge on the same graph (Figure 3-5).

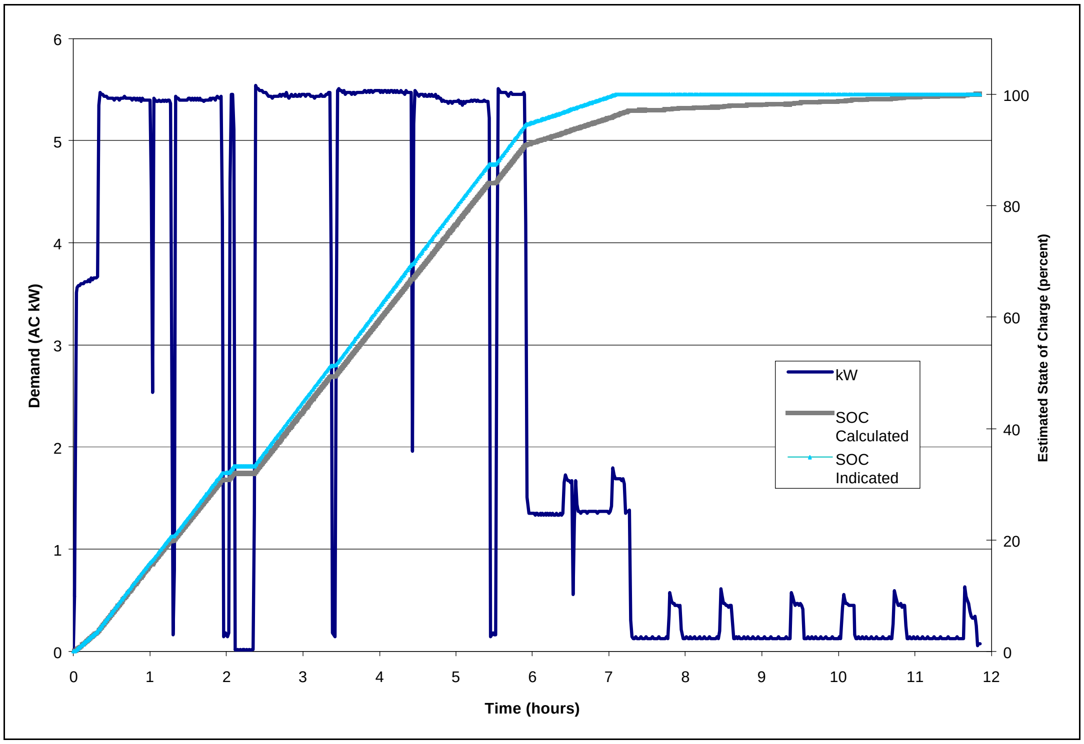


Figure 3-5. Sample AC charging profile plots.

From the BMI and SmartGuard data collected, calculate the energy efficiency for the battery/charger/vehicle system by dividing the total DC kWh delivered to the battery pack by the total AC kWh delivered to the charger. Divide the DC kW curve recorded with the SmartGuard by the AC kW curve recorded with the ABB meter to produce a power conversion efficiency curve.

Using instantaneous data captured with the SmartGuard, determine the ripple factor by dividing the AC RMS current flowing through the battery pack by the average current flowing through the pack.

Determine the overcharge factor by dividing the number of DC kWh (or Ah) returned to the battery pack during recharge by the number of DC kWh (or Ah) delivered from the battery pack during discharge.

By observing the DC current and voltage profiles obtained with the SmartGuard, determine the end of charge conditions.

Divide the current short circuit duty for the charging circuit (see page 27 for a line diagram) by the maximum load current. Use the result to apply IEEE 519-1992, *IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems.* Apply the recommendations from the National Electric Vehicle Infrastructure Working Council (October 1997) shown in Table 3-1.

Table 3-1. EPRI IWC EV Charging Standards.

	Level 1 Charging	**Level 2 Charging**
Total Power Factor (minimum)	95%	95%
Power Conversion Efficiency (minimum)	85%	85%
Total Harmonic Current Distortion (max.)	20%	20%
Inrush Current (maximum)	28 A	56 A

5. Audible Noise Levels

Charge the vehicle in a quiet room or chamber. Use a sound level meter to record (on the EVTC-050 form) the charger noise intensity from a distance of one meter from the charger. Present the plot of the recorded data and the average sound level in the Performance Characterization report.

6. Operation and Ergonomics Evaluations

Observe the operation of the charger, and use the collected data, along with information from the manufacturer to determine:

- Charging algorithm (constant current/voltage steps, etc.) – determined by viewing the charging profile.
- Battery monitoring method – from the manufacturer.
- End point determination (time, gas emission, voltage change, etc.) – from the manufacturer.
- Protective features (battery protection, GFCI, etc.)

Examine and record (objectively and subjectively) on form EVTC-020 the user's interface with the charger and any electric vehicle supply equipment (EVSE):

- Switches, indicators, displays
- Dimensions, weight
- Connector types, compatibility

- Ease of use

7. Charging at a Residential Setting
Take the vehicle to a designated residence and charge from the stop condition state of charge (see page 10) to 100% SOC (see page 28 for a line diagram of the designated residence). Use the BMI Power Profiler to record energy and power quality characteristics. Use the portable ABB Recording kWh Meter recording at one-minute intervals to collect AC demand and energy data. Construct a charging profile, as described in task 2 (page 15).

I. STAND-BY ENERGY CONSUMPTION TESTS ("HOTEL" LOADS)

1. Vehicle on Charger

After completing the *Charger Performance Test,* leave the BMI Power Profiler and SmartGuard Control Center connected to the vehicle and install the most sensitive current probes (5A) available for the BMI. For a 24-hour period, record the amount of AC kWh drawn by the charger and the amount of DC kWh delivered by the charger to the battery pack.

2. Vehicle off Charger

After completing the preceding test, disconnect the AC power supply from the charger and continue to record data on the DC side. This data will show how much energy is consumed by the vehicle's stand-by systems, such as thermal management system on high temperature batteries.

J. TRANSFER THE VEHICLE

Return control of the vehicle to Transportation Services Department if an SCE vehicle, or to its owning organization if on loan.

APPENDICES

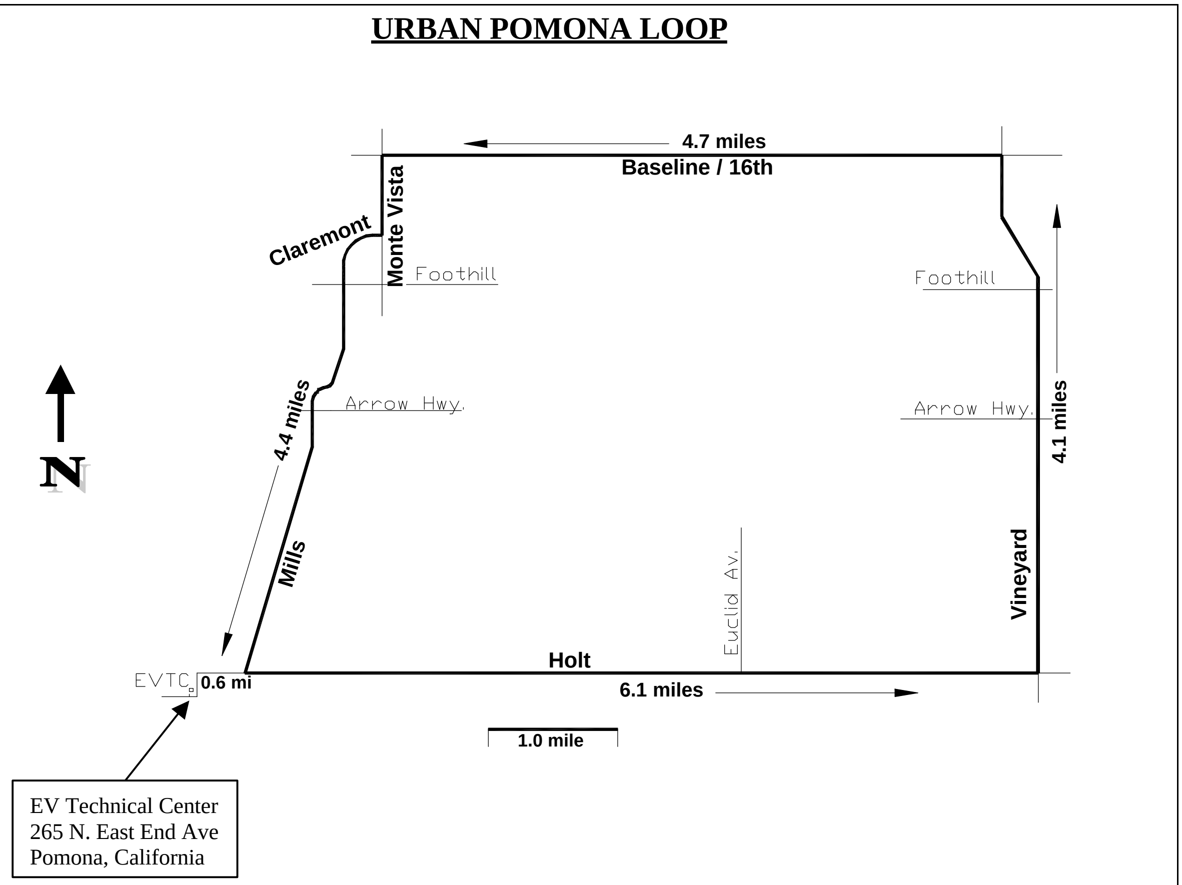
EV Performance Characterization Testing Schedule

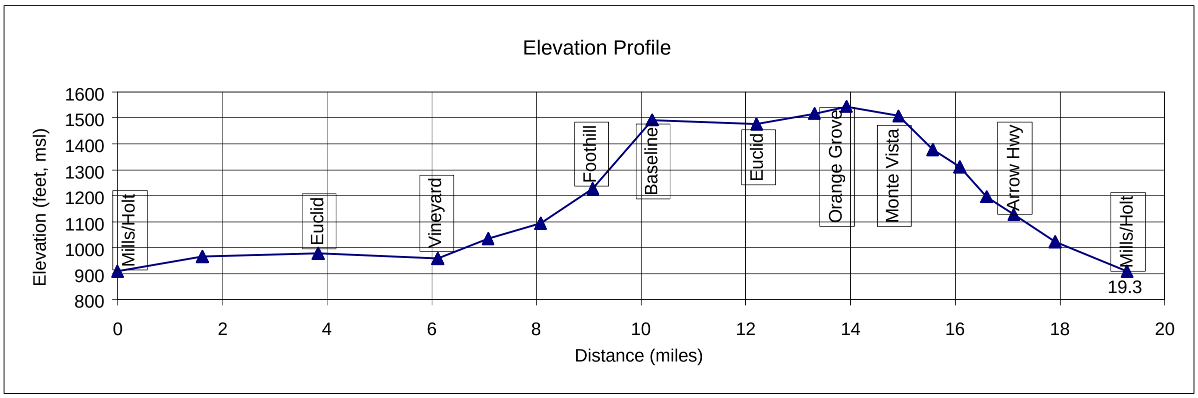
		Duration (days)
1.	Nomenclature Data Collection	½
2.	Weight Documentation - Curb (Front, Rear, Total) - GVWR (Front, Rear, Total)	½
3.	Battery Capacity Test	4
4.	Urban Range Tests - Distance per charge - AC kWh/mile - DC kWh/mile	8
5.	Freeway Range Tests - Distance per charge - AC kWh/mile - DC kWh/mile	8
6.	Sound Level Tests	3*
7.	State-of-Charge Meter Evaluation (Dynamic/Static)	2*
8.	Acceleration / Maximum Speed / Braking Tests	1
9.	Stand-by Energy Consumption Tests ("Hotel" Loads)	2
10.	Charger Performance/Charging Profile Test	3

Minimum total days needed for full testing: 27

* The data gathered for these tests are recorded at the same time that other tests are in progress.

Pomona Loop Map





Urban Pomona Loop - Tabulated Data

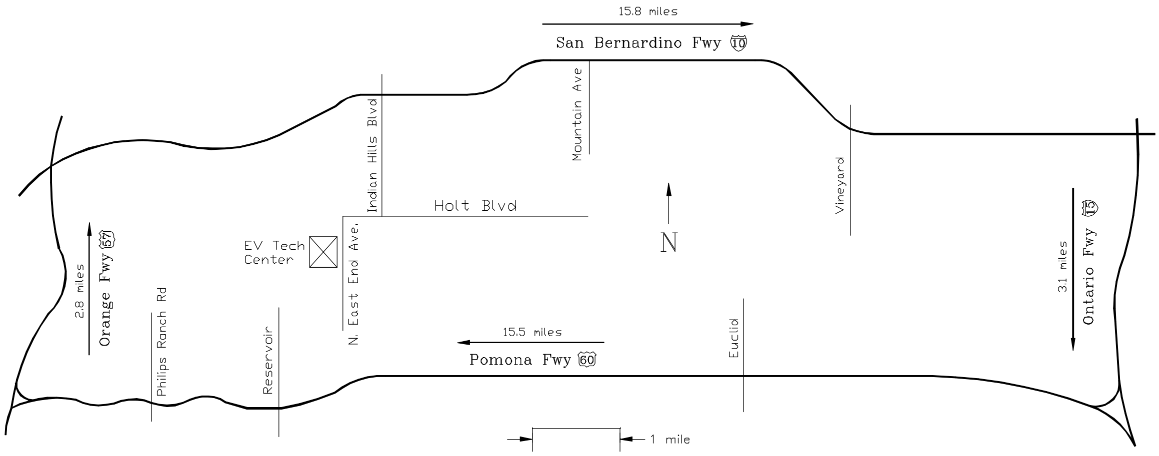
Stop No.	Distance from Start (miles)	Type	Distance from Previous stop	Comments
0	0.00	light	0.00	East End & Holt
1	0.10	light	0.10	
2	0.15	light	0.05	Mills & Holt
3	0.80	light	0.65	
4	1.30	light	0.50	
5	1.80	light	0.50	
6	2.30	light	0.50	
7	2.90	light	0.60	
8	3.50	light	0.60	
9	3.70	light	0.20	
10	4.00	light	0.30	
11	4.01	light	0.01	
12	4.30	light	0.29	
13	4.60	light	0.30	
14	4.80	light	0.20	
15	4.82	light	0.02	
16	5.30	light	0.48	
17	6.30	light	1.00	Vineyard & Holt
18	6.66	light	0.36	
19	6.70	light	0.04	
20	6.80	light	0.10	
21	6.90	light	0.10	
22	7.30	light	0.40	
23	7.80	light	0.50	
24	8.30	light	0.50	
25	8.60	light	0.30	
26	8.80	light	0.20	
27	9.30	light	0.50	
28	9.50	light	0.20	
29	9.60	light	0.10	
30	9.70	light	0.10	
31	10.40	light	0.70	Vineyard & Baseline
32	10.70	light	0.30	
33	10.90	light	0.20	
34	11.60	light	0.70	
35	11.90	light	0.30	
36	12.30	light	0.40	
37	12.50	light	0.20	
38	12.70	light	0.20	
39	13.00	light	0.30	
40	13.60	light	0.60	
41	14.10	light	0.50	
42	15.20	light	1.10	Baseline & Padua
43	16.30	light	1.10	
44	16.80	light	0.50	
45	17.10	sign	0.30	
46	17.40	light	0.30	

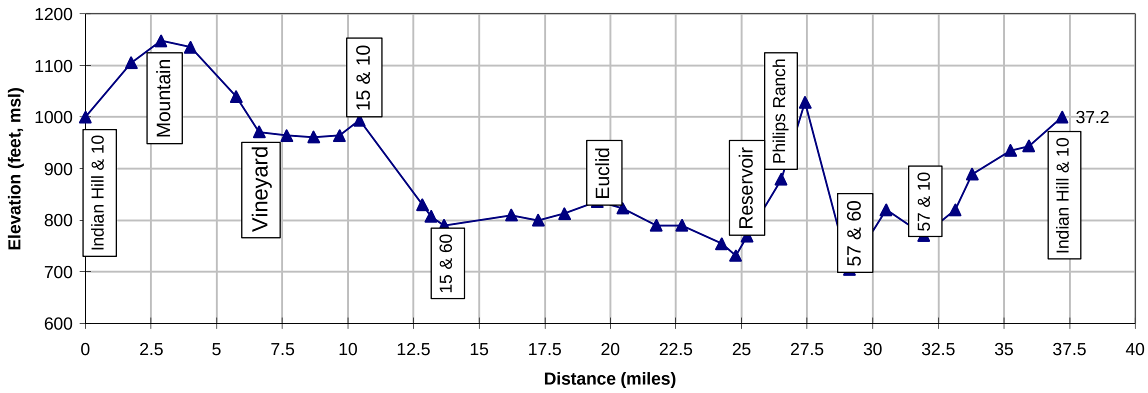
47	17.60	sign	0.20	
48	18.60	light	1.00	
49	18.70	sign	0.10	
50	19.00	sign	0.30	
51	19.30	light	0.30	
52	19.50	light	0.20	Holt & Mills
53	19.60	light	0.10	
54	19.80	light	0.20	Holt & East End

MCW: ttt
9/23/92

Freeway Loop Map

FREEWAY POMONA LOOP





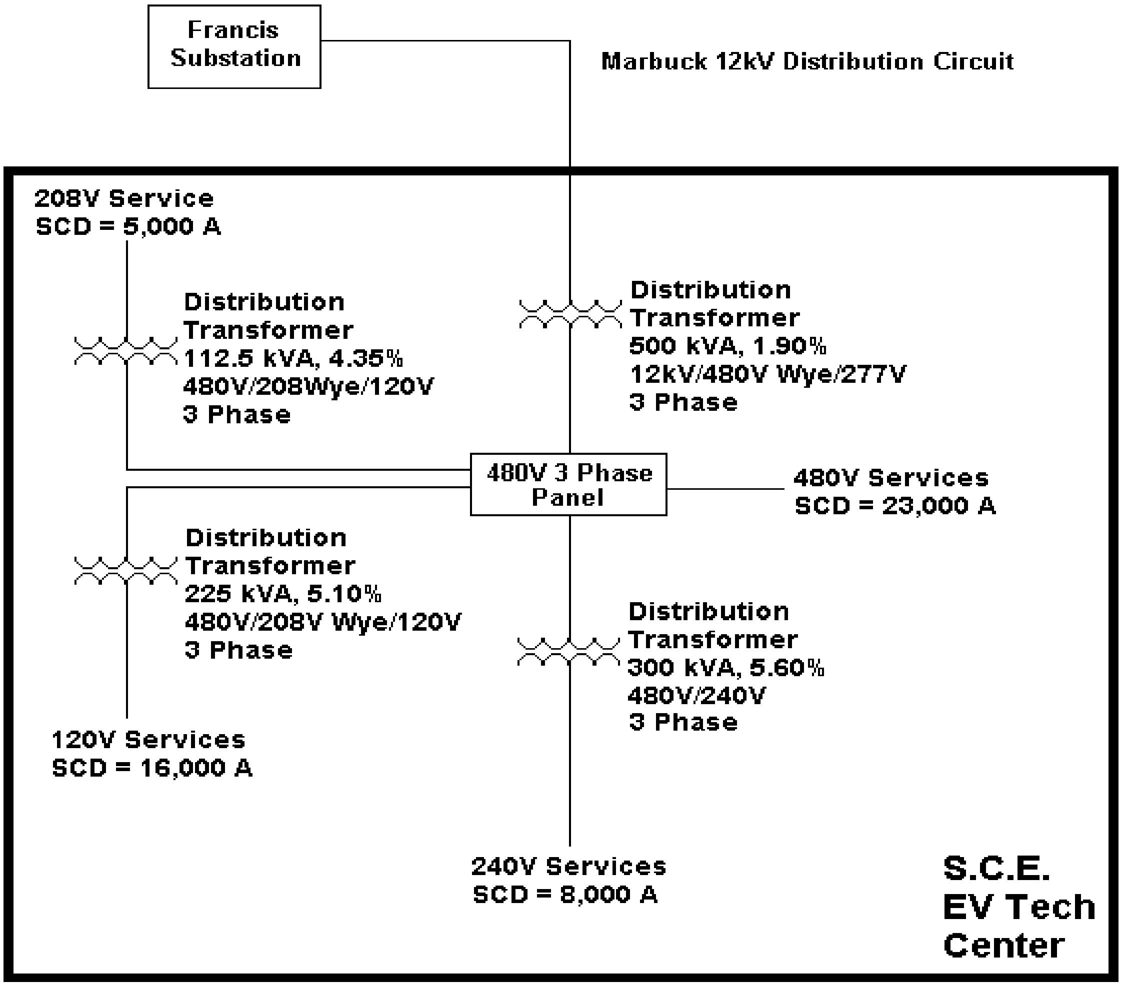
EVTC Equipment

EVTC Number	Manufacturer	Model	Description	Quantity
ABB-001	ABB	A1T-L	PORTABLE KWH METER	4
ACD-001	Various	PC140HS	DC/AC INVERTER	5
AMC-001	FLUKE	33	TRUE RMS CLAMP AMMETER	3
AVI-001	AEROVIRONMENT	ABC-150	ADVANCED BATTERY CYCLER	2
BCH-001	PHILLIPS	PM8906/003	NICD 4C 6V CHARGER	1
BMI-001	BMI	3030A	POWER PROFILER	2
CHG-001	Various	Various	PORTABLE BATTERY CHARGER	3
CHG-002	LA MARCHE	A70B-45-108LBD1	NICD BATTERY CHARGER	1
CMA-001	Various	Various	CAMERA DIGITAL/35 mm	4
CMP-001	Various	Various	DESKTOP COMPUTER	18
CPB-001	BMI	A-115	CURRENT PROBE 60A	3
CPB-004	BMI	A-116	CURRENT PROBE 600A	6
CPB-010	BMI	A-120	CURRENT PROBE 3000A	3
CPB-013	BMI	A-705	CURRENT PROBE 5A	1
CPB-014	FLUKE	80I-1000S	600A AC DMM PROBE	3
CPB-017	FLUKE	80I-500S	500A AC SCOPE PROBE	3
DAP-001	FLUKE	Y8100	DC/AC CURRENT PROBE	3
DAP-004	FLUKE	801-1010	DC/AC CURRENT PROBE	1
DAP-005	TEKTRONIX	AM503B	AC/DC CURRENT PROBE SYSTEM	1
DAP-006	TEKTRONIX	A6303	AC/DC HIGH CURRENT PROBE	1
DAP-007	FLUKE	80I-110S	100A AC/DC PROBE	2
DAQ-001	HEWLETT PACKARD	3497A	DATA ACQUISITION UNIT	1
DAQ-002	HEWLETT PACKARD	3421A	DATA AQUISITION CONTROL UNIT	6
DAQ-008	FLUKE	DAC	DATA AQUISITION CONTROL UNIT	2
DAQ-010	HEWLETT PACKARD	3498A	DATA AQUISITION UNIT	1
DAT-001	OMEGA	HH-F10	AIR SPEED INDICATOR	1
DAT-002	CHRYSLER CORP	SCAN TOOL	EPIC DIAGNOSTIC TOOL	2
DAT-004	HEWLETT PACKARD	Z1090A	GM TECH 2	1
DCG-001	PROPEL	ABT85-220	BATTERY DISCHARGER	1
DCG-002	PROPEL	ABT100-350	BATTERY DISCHARGER	1
DPM-001	YOKOGAWA	2533E43	DIGITAL POWER METER	1
DPS-001	ICC	ICC-21000005-12	DC POWER SUPPLY 13V	2
DPS-002	STANCOR	W120DUJ50-1	DC POWER SUPPLY 12V	1
DPS-004	HEWLETT PACKARD	6479C	DC POWER SUPPLY	1
DPS-005	HEWLETT PACKARD	6448B	DC POWER SUPPLY	1
DVM-001	HEWLETT PACKARD	3456A	DIGITIAL VOLTMETER	1
DYN-001	VERICOM	VC2000PC	PERFORMANCE COMPUTER	1
EDE-001	BERNOULLI	ED	EXTERNAL DRIVE	1
EMT-001	CRUISING EQUIPMENT	RS-2323	E-METER	3
ENV-001	ASSOCIATED ENV.SYS.	ZFK-5116	ENVIRONMENTAL ENCLOSURE UNIT	3
EVC-001	MAGNECHARGE	FM 100	INDUCTIVE CHARGER	3
EVC-004	MAGNECHARGE	WM 200	INDUCTIVE CHARGER	3
EVC-020	MAGNECHARGE	FM 200	INDUCTIVE CHARGER	13
EVC-042	MAGNECHARGE	P200	1.2 KW INDUCTIVE CHARGER	2
EVC-007	EVI	ICS-200	CONDUCTIVE EVSE	10
EVC-014	EVI	MCS 100-3	CONDUCTIVE EVSE (EVI-100) AVCON	2
EVC-017	SCI	GEN1	CONDUCTIVE EVSE/ODU	2
EVC-019	SCI	GEN 2	CONDUCTIVE EVSE/AVCON	7
FGE-001	SHIMPO	MF	FORCE GAUGE	1
GPB-001	HEWLETT PACKARD	GPIB-422CT	GPIB CONTROLLER	1
IST-001	BK PRECISION	1604A	ISOLATION TRANSFORMER	1
ITR-001	NEWPORT	OS520	INFRARED THERMOMETER	1
ITR-002	BMI	A-003	TEMPERATURE SENSOR	1
LPC-001	Various	Various	COMPUTER LAPTOP	9
LPP-001	TOSHIBA	PA2711U	DOCKING PORT	2

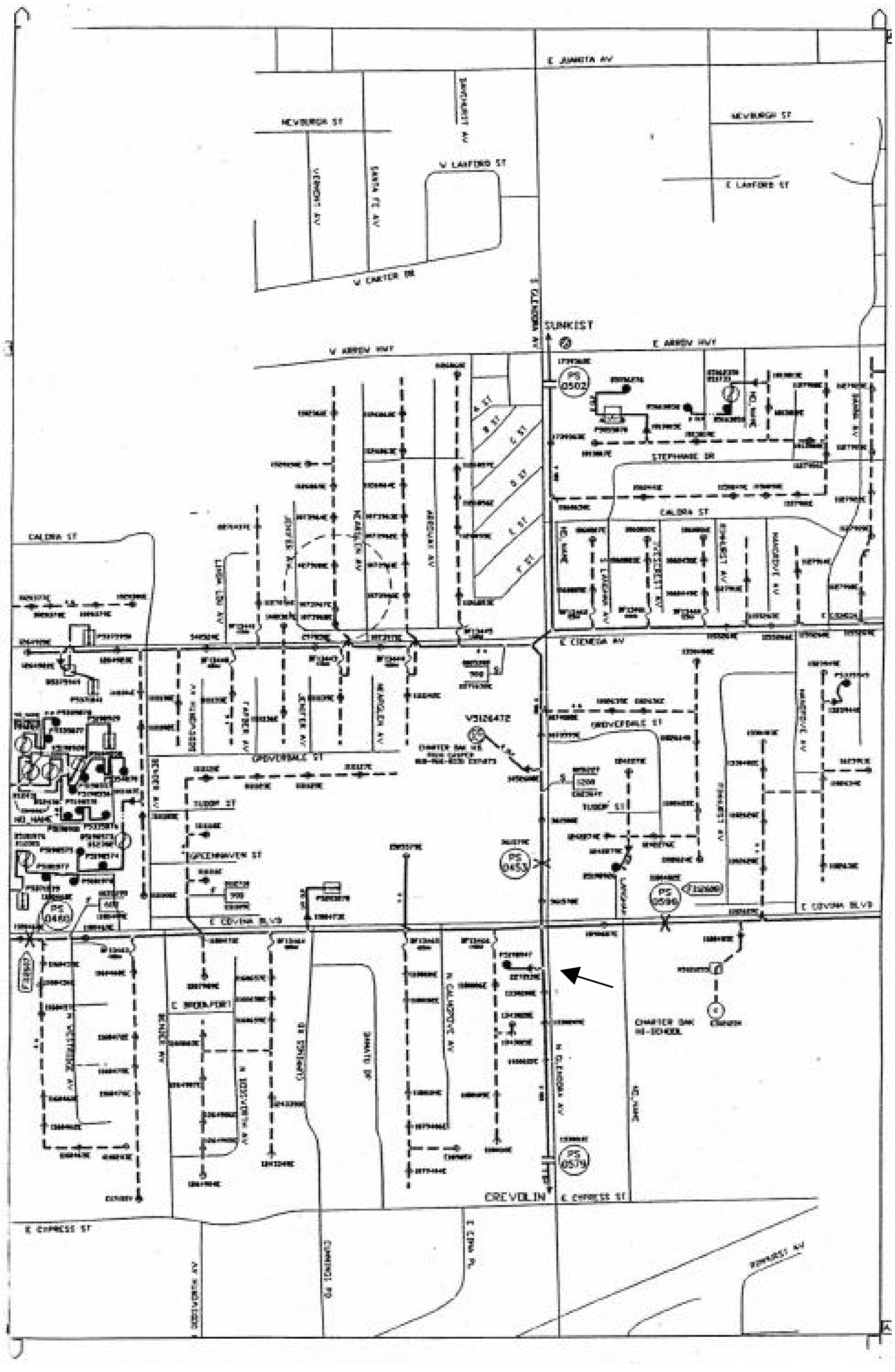
EVTC Number	Manufacturer	Model	Description	Quantity
MCR-001	OLYMPUS	MICRO-32	MICRO CASSETTE RECORDER	1
MMR-001	Various	Various	DIGITAL MULTIMETER	14
MMR-012	HEWLETT PACKARD	34401 A	MULTIMETER	1
MMW-001	ROLATAPE	MEASUMASTERMM30	MEASURING WHEEL	1
MPG-001	HEWLETT PACKARD	6942A	MULTIPROGRAMMER	1
NVK-001	NORVIK TRACTION INC.	BC-500-4	MINIT CHARGER	1
OHM-001	MEGGER	210200	OHM METER	1
OPB-001	U.S. MICROTEL	PM-500	OPTICAL PROBE	2
OSC-001	HEWLETT PACKARD	54600B	OSCILLOSCOPE	1
OSC-002	YOKOGAWA	701810-1D	DL708 DIGITAL SCOPE	1
OSC-003	YOKOGAWA	OR3412/PM-M	OSC. RECORDER H.A.	1
OVP-001	3M	9700 9000AJJ	OVERHEAD PROJECTOR	1
PHA-001	FLUKE	41	POWER HARMONICS ANALYZER	1
PHA-003,4	FLUKE	43	POWER HARMONICS ANALYZER	2
PHA-002	BMI	155	HARMONICS METER	1
PRI-001	EXTECH	480300	PHASE ROTATION TESTER	1
PRT-001	HEWLETT PACKARD	C3167A	LASERJET 5SI/MX PRINTER	1
PRT-002	HEWLETT PACKARD	C2001A	LASERJET 4M PRINTER	1
PRT-003	HEWLETT PACKARD	C4530A	2000C COLOR PRINTER	1
PSY-001	WAYNE-KERR	LS30-10	POWER SUPPLY	1
SCL-001	METTLER	FEHD-R	DIGITAL SCALE	1
SCR-001	FLUKE	97	SCOPEMETER	1
SGM-001	KEM	DA-110	DENSITY/SPECIFIC GRAVITY METER	1
SGN-001	WAVETEK	191	SIGNAL GENERATOR	1
SMR-001	EXTECH INSTRUMENTS	407762	SOUND LEVEL METER	1
STW-001	Various	Various	STOPWATCH	2
THR-001	OMEGA	PTH-1X	TEMP/HUMIDITY METER	2
THR-002	Various	Various	THERMOCOUPLE THERMOMETER	3
THR-004	SEALED UNIT PARTS	PT-100	DIGITAL THERMOMETER	1
THR-006	RADIO SHACK	63-867A	DIGITAL TEMP/HUMIDITY METER	2
WHR-001	CRUISING EQUIPMENT	KWH METER	KILOWATT-HOUR METER	2
YOK-001	YOKOGAWA	AR1100A	ANALYZING RECORDER	1
ZIP-001	IOMEGA	Z100PS	ZIP HARDWARE	3

JWS 4/15/99

EV Tech Center Line Diagram



Residence Line Diagram



EVTC-010 Driving Test Data Sheet

POMONA DRIVING TEST DATA

Date	Vehicle	VIN last 6	Test	Driver	Data File/Project		Volts
						Start	
Road Cond	Tire Press	Payload				Stop	
						Net	

Driving	Time	Odom	% SOC	DC Ah	DC kWh	Amb temp	A/C temp	A/C>10 min
Start								
Stop								Min. A/C
Net								

Distance	State of Charge		Notes / Deviations / Traffic / Weather / Performance
Miles	Veh meter	Range meter	

Accessories used: ____________________

Drive / Regen setting: ____________________

Handling/Braking: ____________________

Other comments: ____________________

Charger	Serial No.		AC meter#		BMI #

Charging	Date	Time	AC kWh in	BMI kWh in	DC kWh in	DC Ah in	Amb temp	Volts
Start								
Stop								
Net								

Comments: ____________________

EVTC-010

EVTC-020 Charger Testing / Analysis Data Sheet

Technician: ____________________________ Date:______________
Location:______________________________ Phone:_____________

<u>Charger Information</u>

Manufacturer: ______________________________________
Model No.: ____
Supply Side Voltage Rating: __________________________

<u>After Completion of Recharging Cycle</u>

Time of Day: _________________________
Final Pack Voltage: ___________________
AC kWh Used: _________________________ DC kWh Delivered: _____________
System Energy Efficiency: ___________________ (DC kWh/AC kWh)
Amp-hours to battery: _________________________kWh to battery: __________________
Overcharge Factor: ___________________ (Ah removed/Ah returned)
DC Output Ripple Voltage: ______________ Ripple Frequency: _____________

<u>Charger Operation Information/Evaluation</u>

Exterior Dimensions: ____________________ Weight: __________________
Charging Profile Type: ____
End Point Determination Method: ____
Battery Monitoring Method: ____
Programmable Charging Profiles: ____
Connector Type(s): ____
Safety Features / Protection Devices: ____
Agency/Industry Approvals: ____
Installation Techniques/Requirements: ____
Appropriate for Interior and/or Exterior Use: ____
User Interface (Switches, Indicators, Display):____
Ease of Use: ____
Current & Future Cost: ____
Warranty: ____
Reliability History / Manufacturer Reputation: ____
Maintenance Schedule: ____
Accompanying Supplies: ____
Manufacturer Support: ____
Other Notes:____
____
____
____
____

EVTC-030 Performance Testing Data Sheet

ACCELERATION, MAXIMUM SPEED, AND BRAKING TESTS

Vehicle No.: ____________
Location: ____________
Date: ____________

	Start	Stop
Time:		
Temp.:		
Odometer:		

Acceleration (100% SOC)

	0-30 mph	0-60 mph	Direction	Max. Speed	30-55 mph
1					
2					
3					
4					

Average ____________

Acceleration (80% SOC)

	0-30 mph	0-60 mph	Direction	30-55 mph
1				
2				
3				
4				

Average ____________

Acceleration (60% SOC)

	0-30 mph	0-60 mph	Direction	30-55 mph
1				
2				
3				
4				

Average ____________

Braking 25-0 mph, 50% SOC

Feet	inches	Total feet	Direction	
				1
				2
				3
				4
				5
				6
				7
				8
				9
				10

____ Average ft

Acceleration (40% SOC)

	0-30 mph	0-60 mph	Direction	30-55 mph
1				
2				
3				
4				

Average ____________

Acceleration (20% SOC)

	0-30 mph	0-60 mph	Direction	Max. Speed	30-55 mph
1					
2					
3					
4					

Average ____________

Comments ____________

EVTC-040 Vehicle Test Equipment and Nameplate Data Sheet

Project:______________________________ Test:_______________________________
Date(s):______________________ File Name(s):_______________________________
Vehicle Number:______________ Technician:_______________________________

VEHICLE

Manufacturer: ______________________VIN:_______________________________
Model: ______________________Model Year:______ Date of Manufacture: __________
GVWR:________________Front AWR:__________ Rear AWR:__________________
Motor Manufacturer:_________________ Motor Type:_______________________
Motor Rating/Speed:____
Version/Serial No.:____
EPA Label Fuel Economy: ____
Controller Version/Serial No.: ______________________________________
Battery Pack Type/Version/Serial No.: _________________________________
Tire Manufacturer: _______________________Model:_____________________
Tire Size:____________________ Maximum Pressure:_____________________
Maximum Tire Load: __________ Treadwear Rating:______________________

CHARGER

On-board / Off-board Manufacturer:_______________________________
Model: ______________________Serial Number:___________________________
Charger Type/Version:____
EVSE Manufacturer: _______________________________
EVSE Model/Version:_____________________Serial Number:__________________
EVSE Software Version:______________________________
Charge Port Manufacturer/Model/Version/SN:_____________________________

TEST EQUIPMENT

BMI Power Profiler 3030A EVTC Number:_________________________________
ABB kWh Meter Serial Number:_______________________________________
Thermometer EVTC Number:____
Optical Meter Probe EVTC Number:____________________________________
Laptop Computer EVTC Number:_______________________________________
Desktop Computer EVTC Number:_____________________________________
Stopwatch EVTC Number:____
Digital multimeter EVTC Number:_____________________________________
ABC-150 EVTC Number:____
Smart Guard Interface Serial Number:__________________________________
Smart Guard Numbers:____
Sound Level Meter EVTC Number:____________________________________
Measuring Wheel EVTC Number:______________________________
Other Equipment:____

WEIGHT CERTIFICATION

Scale Location and Proprietor:__________________________________
Examiner:______________________________ Date:________________
Notes:____

EVTC-050 Sound Level Meter Data Sheet

Sound Level Test Data

Urban Driving Sound Level Test

Date:	
Project:	
Technician:	
Veh. No.:	
Location:	
Start odo:	
End odo:	
Trip:	

Sound Level Range(dBs):	

	Start	Stop
Recording Time:		

Put a check mark on the settings selected

	A	C
Frequency Weighting:		

	Fast	Slow
Response:		

Comments: ______________________________

Freeway Driving Sound Level Test

Date:	
Project:	
Technician:	
Veh. No.:	
Location:	
Start odo:	
End odo:	
Trip:	

Sound Level Range(dBs):	

	Start	Stop
Recording Time:		

Put a check mark on the settings selected

	A	C
Frequency Weighting:		

	Fast	Slow
Response:		

Comments: ______________________________

Charger Sound Level Test

Date:	
Project:	
Technician:	
Veh. No.:	
Location:	
Start odo:	
End odo:	
Trip:	

Sound Level Range(dBs):	

	Start	Stop
Recording Time:		

Put a check mark on the settings selected

	A	C
Frequency Weighting:		

	Fast	Slow
Response:		

Comments: ______________________________

EVTC-060 Vehicle Battery Constant Current Discharge Capacity Test Data Sheet

Project:________________________ Test File:___________________________
Date(s):________________________ Technician:_________________________
Vehicle Number:____________________ Battery Nos.:_______________________

BATTERY SPECIFICATIONS

Manufacturer: ______________________ Model: ___________________________________
Date of Manufacture: ________________ Nominal Voltage:__________________________
Ah Rating @ C/3:____________________ Voltage Range:___________________________
Weight/Module:_____________________ Temp. Range:_____________________________

BATTERY PACK

Number of Modules:__________________ Nominal Voltage:__________________________
Configuration: ____
Location for Test:____

TEST EQUIPMENT

Discharge Unit: ___________________________ Serial No.___________________________
Charging Unit: ____________________________ Serial No.___________________________
Data Acquisition Equipment:____

____
Other Equipment:____

RESULTS

	TEST 1	TEST 2	TEST 3
DATE			
DISCHARGE (A)			
STOP CONDITION			
START TIME			
STOP TIME			
TOTAL TIME			
START TEMP.			
STOP TEMP.			
START O.C. VOLTS			
STOP O.C. VOLTS			
ΔV at STOP			
Ah OUT			
kWh OUT			
LOWEST MODULE			
DATA FILE			

RECHARGE TYPE			
Ah RETURNED			
kWh RETURNED			
DATA FILE			

NOTES:____

____